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Report on trip to California

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Report on Trip to California

M. Heineman

Itinerary

[1949]

April 8 - Flew from New York to Houston.
April 9 - Stayed in Houston.
April 10-12 - Traveled by train from Houston to Pasadena.
April 13-17 - Stayed in Pasadena.
April 18 - Flew from Los Angeles to San Francisco.
April 19-27 - Stayed in Berkeley.
April 28 - Flew to Washington.

The purpose of this visit was to become acquainted with the work that is being done on the low-pressure wind-tunnel at the University of California in Berkeley. However, as I first wanted to go to Houston, Texas, this seemed like a good opportunity to visit also the California Institute of Technology in Pasadena. In the following report, no attempt will be made to present the events in their correct chronological order.

Low-pressure work at Berkeley.

The group is headed by Dr. R. G. Folsom, Professor of Mechanical Engineering, Dr. S. Schaaf, Assistant Professor of Mechanical engineering who is directing the theoretical work, and Dr. E. D. Kane, Lecturer in Mechanical Engineering. During the past year a pilot tunnel was built with a 1" x 1" test section. The nozzle was of conventional design. The most important piece of information derived from experiments with this tunnel was that with the type of nozzle shown and for pressures of about 10 microns, the boundary layer build-up is so great as to fill nearly the

whole cross section of the tube. This makes it difficult to attain supersonic speeds.

The tunnel that is now being built has a 10" x 10" test section; the pressure is approximately 10 microns, the mean free path, 3/10". It is designed to operate at Reynolds numbers from 500 to 1500 and at Mach numbers up to 2.5.

One of the main problems is flow visualization. Obviously, at these low pressures, the usual methods cannot be used. The method that is now being tried is based on the property of O_2 by which it strongly absorbs radiation of 1500 A°. The variations in intensity of the transmitted light are proportional to the density gradient.

Another very great difficulty is the design of a suitable nozzle, i.e., one in which the boundary layer growth is not too great. Shown below is a side-view of the type of nozzle being tested at the time. It is essentially a two-dimensional nozzle.

The Berkeley group is very anxious for members of our group to work on this problem of designing a suitable nozzle. However, it involves solving the two-dimensional Navier-Stokes equations with compressibility taken into account. From experimental data, it seems reasonable to assume that no slip occurs at the walls. One must also take into account the fact that the boundary layer is not only viscous but also partially supersonic. No breaking away has been observed. Dr. Schaaf has applied the Pohlhausen method and has reduced the problem to a point where it can be integrated numerically. However, the cost of doing this would be very great.

For the past few months, Dr. Schaaf has been toying with the idea of designing a nozzle consisting of a brass plate, about 1/2" thick, and drilled through with holes whose

diameter is of the order of a mean free path.

Other low pressure apparatus that are being built are

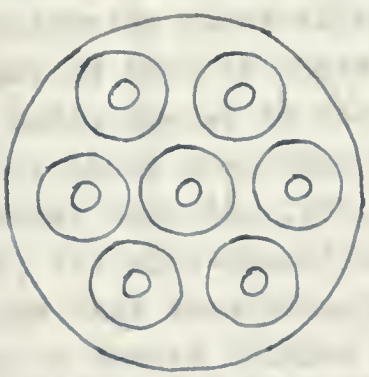
(a) A molecular beam apparatus.

(b) A subsonic wind-tunnel designed to operate in the free molecular flow region.

The group is also planning to build a rotating cylinder apparatus with which to test Schamberg's boundary conditions. Some of the projected experiments are the study of the reflection of molecular beams from surfaces, the scattering of molecular beams by gases, the effect of relaxation time on the thickness of shock waves, the velocity distribution in boundary layers.

Low-pressure wind-tunnel at Moffett field.

A group headed by Dr. J. R. Stalder is building a supersonic, low-pressure wind-tunnel at Moffett Field. The test section is 3" x 3", the pressure, 100 microns (slip-flow region) and so far, Mach numbers of about 2 have been obtained. They intend, however, to reach Mach numbers up to 7. They are having the same difficulties with boundary layers as the Berkeley group and have already produced a nozzle of the same type as that proposed by Schaaf. A drawing of it is shown below. Each of the holes is approximately 1/4" in diameter at the high pressure side and 1/2" on the low pressure side. However, at the time I was there, this nozzle had not yet been tested.



The Moffett field group is not building any low-pressure apparatus besides the wind-tunnel in which they intend to carry out ~~positive~~ routine tests on models. Hence, there should not be too much duplication with the work of the Berkeley group. Dr. Stalder told me that they need people to do theoretical work on these

problems and seemed anxious to keep in touch with our Institute. He and D. Jukoff have recently written a paper on "Heat transfer to bodies traveling at high speed through the upper atmosphere," printed as an NACA report.

Among other people I met in Berkeley were Profs. Brode and Powell of the physics department who very kindly showed me some of their cosmic ray equipment and took me around the radiation laboratory; also Dr. Grossman, who is engaged in experimental research in the field of non-isotropic turbulence in liquids. I was also able to visit the physics laboratories at Stanford University, including the nuclear induction apparatus and the election linear accelerator which is in the process of being built.

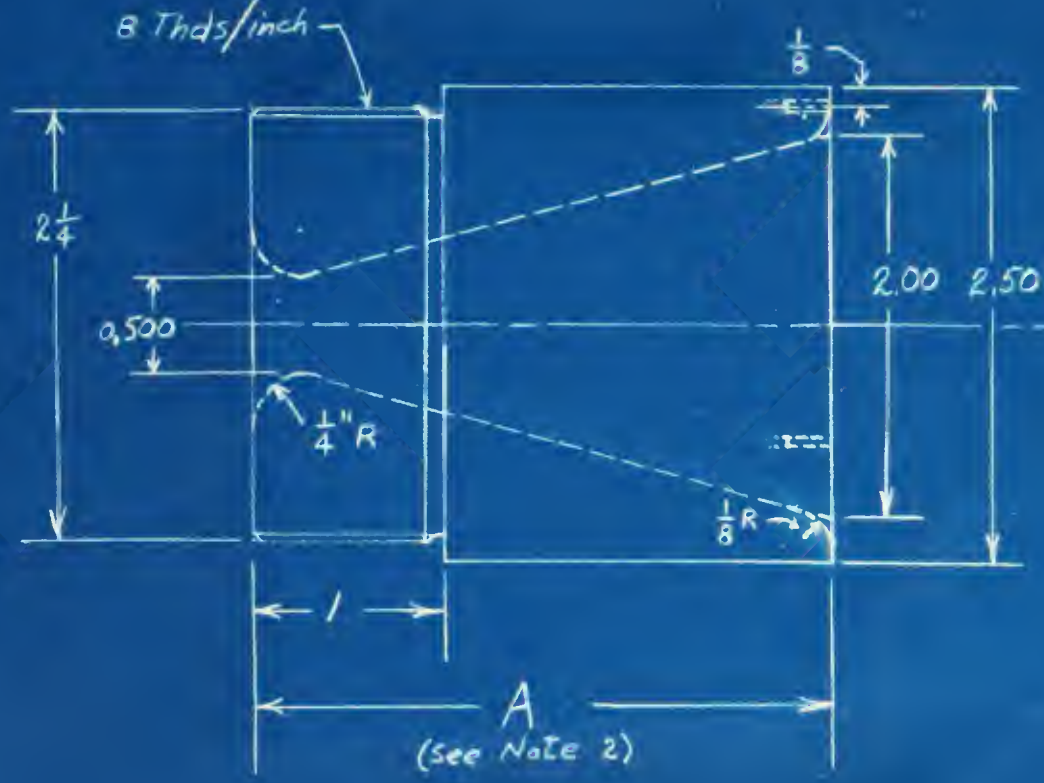
Pasadena.

I spent most of the time at the California Institute of Technology where I met the following people: Profs. Epstein and Plesset of the Physics Department, Liepmann and Laufer of the Department of Aeronautics, DePrima of the Mechanical Engineering Department. Liepmann and Laufer are largely engaged in studying isotropic and non-isotropic turbulence in gases. They use the usual hot-wire method for measuring correlations. So far, they say their results are not as good as those of G. I. Taylor, mainly because of some deficiencies in the design of their electronic circuits. Some of their more recent results are included in the NACA Technical Note No. 1257, August 1947. At the time of my visit, the wind-tunnel was not functioning due to some changes that were being made. With the new tunnel, Liepmann hopes to obtain thicker boundary layers that are largely supersonic. This would enable him to obtain more satisfactory results on Mach reflection.

Plesset is still engaged in research on cavitation drag. Using Riabouchinsky's method of images, he has calculated the cavitation drag on a wedge of arbitrary angle in an infinite stream. He has extended these results to cones of revolution; this approximation appears to be good as the theoretical results check well with experiment except for very small angles. The explanation for this discrepancy is not yet known. Experiments are in progress to determine the pressure distribution on 3-dimensional bodies of revolution in cavitating flow. Professor Plesset showed me the laboratory where these experiments are being done. It was interesting to observe the formation of the re-entrant jet in cavitating flow on which the theory of Prandtl and Wagner is based. Other equipment included a ripple tank and two tanks used for the study of water entry phenomena. Plesset is also doing some research in nuclear physics, namely, on the multiple scattering of γ rays. The methods used might bear some relation to those for calculating drag in rarefied gases when collisions are taken into account.

I was pleased to have the opportunity to talk to R. Schamberg and Kruger who are both working for the Rand Project of Douglas Aircraft at Santa Monica. Kruger is doing some work in rarefied gases but Schamberg has now abandoned this field and is working in the region of ordinary gas dynamics. I gave Schamberg some of my results on drag as he wants to include these in an article he is writing on superaerodynamics. We talked about the boundary conditions he derived for the slip flow region but I am still not sure that I understand the justification. I was not able to find out anything about the work that is being done on the project as all phases of it seem to be classified. During the remaining time in Pasadena, I visited the Coop wind-tunnel and spent an afternoon at Mount Wilson where I was shown round by Mr. J. O. Hickox, one of the astronomers; I also drove down to La Jolla and spent a short time at the Scripps Institute where I met Dr. Walter Munk.

Series A



NOTES

1. MATERIAL - BRASS
2. MAKE 3 NOZZLES:

NOZZLE NO.	DIMENSION A
A-1	2"
A-2	4"
A-3	6"

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